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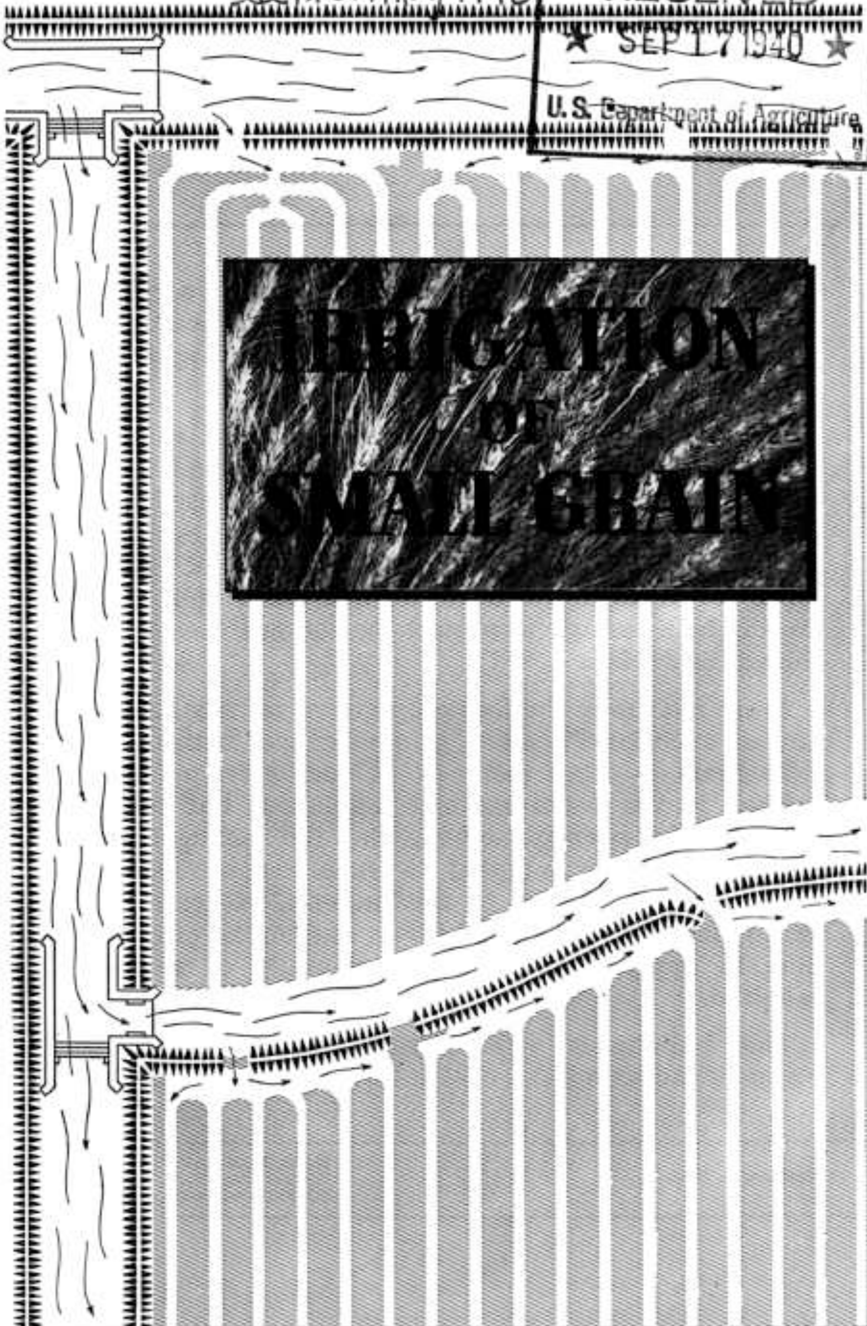

FARMERS' BULLETIN No. 1556
U. S. DEPARTMENT OF AGRICULTURE

GRAIN IS GROWN on irrigated farms, as a rule, only in localities having short growing seasons, on new land, or where grain is included in a system of rotation.

Methods of irrigating grain are restricted somewhat because the crop covers the entire ground surface. Objections to the flooding method—based on the loss of water by evaporation—have less weight in the irrigation of grain than in the case of most other crops, since water seldom is applied until the crop is high enough to protect the soil surface from the sun and wind.

Grain is usually the first crop grown on new land, and on such land flooding generally gives better results than do other methods. Flooding from field ditches is the usual method employed, but wild flooding, the border method, and the corrugation method also are adapted to such crops. These methods are discussed in this bulletin, as are also the preparation of the land for irrigation, the proper time to apply water, and the quantity of water required.

This bulletin is a revision of and supersedes Farmers' Bulletin 863, entitled "Irrigation of Grain."

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IRRIGATION OF SMALL GRAIN

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CONTENTS

INTRODUCTION

As a rule grain is the first crop grown on newly cultivated land, but few irrigated farms can be made to pay if permanently devoted to it. Hence in well-established irrigated sections, grain is grown only as a secondary crop in a rotation, or to utilize land with water supplies insufficient to mature more remunerative crops.

The yields of irrigated grains are considerably higher than those obtained by dry-farming methods, but a yield of even 40 or 50 bushels of wheat per acre is not enough to warrant its continued production under irrigation where more valuable crops can be grown.

This bulletin is concerned primarily with the irrigation of small grain (wheat, oats, and barley) on new land.

PREPARING THE LAND FOR IRRIGATION

The settler on a new farm is likely to be too busy erecting his buildings and clearing and planting his land to devote enough attention to the proper preparation of the land for irrigation. Therefore he obtains better returns the first year from grain, corn, and potatoes than from other crops. These crops mature with limited moisture and thrive exceptionally well on new land.

Before permanent crops, such as alfalfa, are planted, the field should be leveled carefully and irrigated. Usually, if the crop is alfalfa, there is not time to do this and then relevel the field before planting must be done; but grain may be seeded and irrigated through the season, during which time the farmer may determine where the surface needs further dressing off or filling in. This

[1] On July 1, 1939, the Soil Conservation Service took over most of the irrigation investigations formerly conducted by the Bureau of Agricultural Engineering.

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releveling can best be done after the grain has been removed but before the land has been replowed, the water marks serving as guides in filling depressions or in leveling down knolls.

It is common practice, where the growing of winter grain is possible, to follow this final leveling with the seeding of fall grain as a nurse crop for alfalfa. If the planting is done early enough in the season alfalfa is seeded at the same time; otherwise it is seeded the following spring. This practice leaves the ground in good condition for the irrigation of all later crops.

ADAPTABILITY OF WINTER GRAIN

In recent years winter wheat has taken the place of spring wheat to a considerable extent in portions of the arid region. This is because it has been found, quite contrary to ideas prevailing even 10 years ago, that winter wheat will stand extremely low temperatures without winter killing, when the seed bed is suitable for germination and the crop is sown early enough for the plants to reach the stooling stage before freezing weather stops their growth. Furthermore, irrigation water can be used to far better advantage on winter grains than on spring grains. In many localities winter precipitation is insufficient to furnish the moisture essential to germination and to carry the crop to the stooling stage. It is therefore necessary to apply water to the land either before or very soon after seeding in order that germination may be complete and the crop given the proper start.

When irrigated during the very early stages of growth, grain is likely to be injured by the operation, or at least retarded in growth, as compared with the crop grown in a seed bed which contains sufficient moisture to keep it growing without irrigation until a later stage of development.

Winter grain, if it reaches the stooling stage before freezing stops its growth, is in condition to grow rapidly as soon as spring weather comes. Where fall and winter precipitation has been light, spring irrigation is required to produce a full crop. In that case the water may be applied during the early season when it is most plentiful. Usually the crop is matured early in the summer before the period of low-water supply has advanced very far. Spring grain will require at least one more irrigation than is necessary for winter grain because of the difference in development at the beginning of the spring growing season, and because of the corresponding difference in maturity. This is especially true if spring grain is seeded on spring-plowed land.

IRRIGATION AND THE SEED BED

The most vital operation in the season's work in producing a crop of grain is the preparation of the seed bed and the most important consideration in establishing a proper seed bed is that of providing an adequate moisture supply. It is essential to the production of a maximum crop that the seed bed contain sufficient moisture to carry the crop at least to the stooling stage without further irrigation. This applies particularly to spring grain and in a more general way to winter grain. The mistake of "irrigating the crop up" is made

all too frequently in districts where irrigation for germination is necessary.

The importance of irrigation in preparing the seed bed must not be minimized. This is true for grain generally, but particularly for spring grain, and especially where the soil is inclined to bake. Where the soil is dry at plowing time it is desirable to irrigate before plowing. In the fall it will hardly be necessary to irrigate after plowing, but in spring it frequently happens that in the process of plowing the soil is dried out to such an extent that irrigation is necessary either before or after seeding in order to secure satisfactory germination. In either case if irrigation is necessary for germination it is better to apply the water before seeding rather than afterwards.

In the process of irrigating a freshly plowed seed bed the soil is compacted, and if inclined to bake it may become rather hard before drying sufficiently to permit seeding. Sometimes the farmer makes the mistake of using a disk on such a soil to prepare it for seeding. He should bear in mind that the surface soil will dry out as deep as it has been stirred. Therefore disking may result in drying the soil so deep as to prevent uniform germination. It is better to follow the irrigation with a spring-tooth or a spike-tooth harrow in order to break the crust and pulverize the surface soil fine enough to permit seeding. In this way the seed may be placed well into the moist soil and uniform germination will follow.

One further precaution should be taken with reference to early irrigation. It is essential that the subsoil as well as the surface soil be moist at seeding time. Frequently it will be found by digging into the soil that it is dry a short distance beneath the surface. If this be the case, the soil is in no condition to start and continue the growth of a maximum crop. The needed moisture must be added, especially before spring seeding. In fact, this is the most necessary irrigation of the season. A soil containing a full supply of moisture at seeding time, whether it be fall or spring, stands a much better chance of producing a full crop than does a soil that has barely enough moisture for germination.

METHODS OF APPLYING WATER

Three principal methods are in common use in the irrigation of grain: (1) The furrow or corrugation method, (2) wild flooding, (3) flooding from field laterals either with or without the aid of borders. The first two methods are in common use on new land and on old land that has not been prepared for a better system of application. Other modified methods may be used to advantage under certain conditions, but where such conditions exist the irrigator does not need the assistance which this bulletin is intended to render.

These methods of irrigation require field laterals and distributing ditches, and the most essential features of these will be described.

FIELD LATERALS AND DISTRIBUTING DITCHES

In the following discussion, farm laterals are the branches of the irrigation system which lead from the main supply ditch or lateral to the head ditch, the latter being the main ditch across the

upper end of each subdivision of the farm. Field laterals carry water from the main head ditch to distributing ditches within the farm subdivision. A cross ditch is a ditch which leads the water across the field and distributes it to the corrugations or to the outlets from which the land is flooded.

Field laterals parallel each other and of necessity run down the steepest slopes. For this reason it is necessary to install drops, or to line the ditch, where the slope is such as to cause the stream to wash or erode the soil. Such improvements may be installed in advance, but as a rule the necessity for them is demonstrated by experience.

Head ditches run across the upper ends of the fields or subdivisions of the farm and generally at right angles to the farm laterals. Field laterals and head ditches may be made permanent and may be controlled by permanent gates at the main junction points.

To aid in distributing the water through the openings in the lower bank, cross ditches should be given just enough fall to cause a flow of water. If the slope is uniformly in one direction the cross ditches will be parallel with each other, and practically parallel with the head ditch. These ditches serve to collect the surface run-off from the section of the field next above them for reuse on the section below.

To prevent a waste of water from deep percolation it is sometimes desirable to space the cross ditches rather close together, the actual distance depending upon the nature of the soil and the subsoil. The usual tendency is to space them too far apart. The proper distance is between 200 and 600 feet, but usually not over 300 feet.

METHOD OF CONSTRUCTING FIELD DITCHES

Ordinarily field laterals and head ditches may be successfully constructed by plowing several furrows with a moldboard plow. Beginning at the inside of what is to be the permanent bank and continuing until the last two plowings are up and down the center of the ditch the dirt should always be turned out. A V crowder or a ditcher of some standard make may then be used to remove the loose dirt from the middle and crowd it out to form the bank. If the ditch must be large, several plowings and crowdings will be required, and it may even be found necessary to use a fresno or some other type of scraper to finish the ditch. On smooth ground, however, one complete operation with plow and ditcher usually is sufficient.

A good type of homemade ditcher is shown in figure 1. More elaborate tools are available, such as double moldboard ditchers with wings attached and various patented steel ditchers. Field laterals and cross ditches usually are only temporary and are plowed or disked in before harvest.

METHODS OF DISTRIBUTING FROM FIELD DITCHES

The labor involved in the first irrigation of new land may be lightened by mapping out and constructing the type of distributing system best suited to conditions, and especially by providing in advance for the regulation of the stream. The experienced irrigator observes in advance where trouble may develop and works ahead of

the stream, on dry soil, as the water proceeds down the corrugations or over the surface. This prevents injury to the crop if the seeding has been done.

THE CORRUGATION METHOD[1]

The best method to effect uniform distribution from field ditches to new land, and a method which is very satisfactory under any condition, is known as the corrugation method illustrated in figure 2. The field is laid off in a succession of shallow furrows or corrugations which run up and down the steepest slope and guide the water in such a way as to irrigate the entire field. The cross ditches are made by plowing in one direction thus throwing the dirt downhill, away from the head ditch. This makes a small bank through which water is distributed to the land below.

The openings from the head ditch are made through firm portions of the bank, and as nearly as possible at the same level with the cross

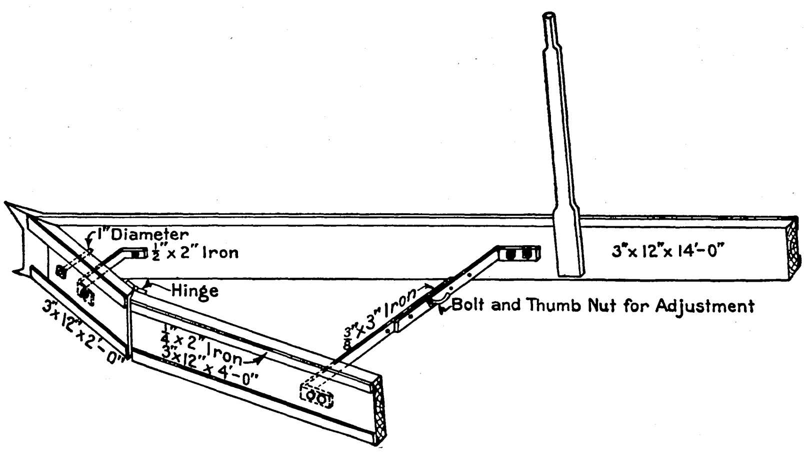

FIGURE 1.—Adjustable V scraper or crowder.

ditch below. If the head ditch runs down a heavy slope it should be built in sections, with permanent drops, so that the water may be held level in a section while distribution is being made. This aids materially in effecting a uniform distribution.

This method saves much hand labor in flooding uneven surfaces. It is easy to reach the high spots, prevents waste of water in low places, and where corrugations are properly located the danger of breaking from one corrugation to another is small. It is next to impossible to succeed with corrugation irrigation when the direction of flow is diagonally across a steep slope, unless the corrugations are made very deep and regular. Even then there is constant danger of a furrow becoming clogged and precipitating its water into the next one, resulting in a combined stream too large for one furrow, which then breaks into the third, and so on until the combined flow runs wild down the slope cutting gullies through the field and destroying the crop.

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[1] More detailed information regarding this method is given in MARR, J. C. THE CORRUGATION METHOD OF IRRIGATION. U. S. Dept. Agr. Farmers' Bul. 1348, 24 pp., illus. 1923.

Several corrugations are usually supplied from one opening in the ditch bank (fig. 2) which should be made in the thickest part of the bank to prevent washing. To save labor and water, the irrigator should make all these openings and provide for distributing the stream as uniformly as possible before the water is admitted to the ditch. In addition, it is well to distribute partly rotted straw or coarse manure in piles along the ditch bank at frequent intervals to aid in controlling the water and prevent washing. If the land is new the harrowing done to prepare the seed bed probably will accumulate roots of sage brush or other rubbish, which can be left at convenient places along the head of the land for later use in controlling the water distribution. Such material aids greatly in effecting a uniform distribution to corrugations during the first irrigation.

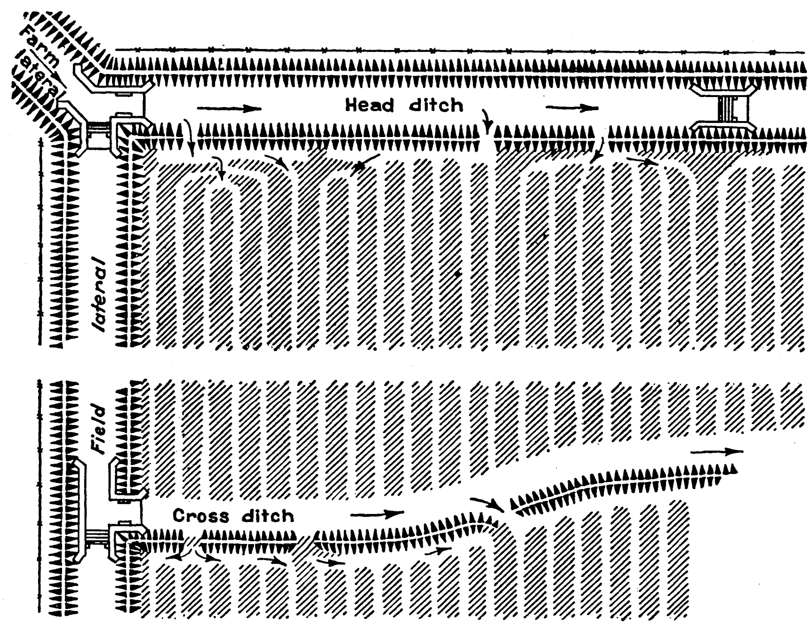

FIGURE 2.—Corrugation method of irrigation showing details of distribution. The white space across the middle of the field indicates that a portion of the drawing is omitted.

When the water has been once distributed evenly and the openings to furrows are once set, conditions should not be disturbed during the season. The shutting off of streams will be confined to the intake of cross ditches or to the main openings from such ditches to the subdivisions leading to corrugations, and it should never be necessary to close the openings to individual corrugations once the flow of water to them has been regulated.

In cases where corrugations take water directly from the head ditch or cross ditch the irrigator is likely to find that he destroys more crop in tramping back and forth and in shoveling dirt into the openings to close them off than he would have done by making an extra cross ditch just below the head ditch or regulating ditches directly below the cross ditches, as shown in figure 2. In making such a layout as the one indicated a moldboard plow is run across the land and back, the backfurrow making a good bank below the cross ditch

and leaving a regulating ditch below the bank, which needs little further preparation to make it ready for the first irrigation.

WILD FLOODING

In some localities wild flooding, or flooding from cross ditches, is practiced, but this method cannot be expected to succeed on new land unless the field is level enough for large heads of water to be used to cover the high points or where, if the slope is steep, the soil is of such a nature as to resist washing.

In either case water will collect rapidly in the depressions, and where the fall is considerable there will be a tendency to uneven irrigation and to erosion. On sloping fields the cross ditches for collecting and redistributing the water must be very close together if the surface is to be covered. As irrigators become experienced wild flooding is abandoned for one or another of the better methods of irrigation.

FLOODING FROM FIELD LATERALS

A system more desirable than wild flooding may be provided by placing the field laterals, leading from a common head ditch, fairly

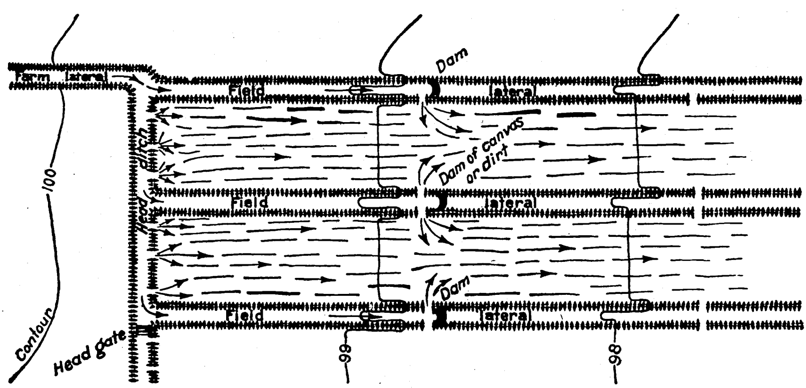

FIGURE 3.—Method of flooding from field laterals.

close together, as shown in figure 3. In this system the laterals run down the steepest slope, dividing the land into parallel strips varying in width from 50 to 250 feet, depending upon the topography of the surface. Water is diverted from these laterals, first at the top of the strip, then at intervals, down the slope, depending upon the character of both the soil and the surface as the watering proceeds.

These field laterals may be made more or less permanent if each strip of land is leveled by itself without regard to the strips on each side, thus providing for a uniform irrigation, which for some lands is superior to any other method. This system of irrigation is best adapted to steep slopes and porous soil.

THE BORDER METHOD[2]

Flooding between borders differs in two respects from flooding from field laterals, as may be seen by comparing figures 3 and 4.

[2] Additional information regarding this method is contained in FORTIER, S. THE BORDER METHOD OF IRRIGATION. U. S. Dept. Agr. Farmers' Bul. 1243, 41 pp., illus. 1922.

In the first place, levees take the place of field laterals and run in the same direction; second, the water is distributed entirely from head ditches if the strips between borders are short, or from both head ditches and cross ditches if the strips are long, as indicated in figure 4. The border method is suited to a wide variety of soils and conditions. When lands are properly leveled crosswise between borders, this is probably the best method to use in irrigating grain or any other crop which will stand flooding.

If the surface is flat and the soil porous, a large head can be used to force the water over the plot quickly and thus provide a uniform application without excessive loss by deep percolation. If the soil is compact, a smaller stream should be used for a longer period of time in order to moisten the subsoil properly.

In using this method to irrigate new land which has just been leveled it is often desirable to mark the surface off into corrugations for the first season, or until the land can be releveled, because of the impossibility of making a perfect job of the leveling the first time it is done.

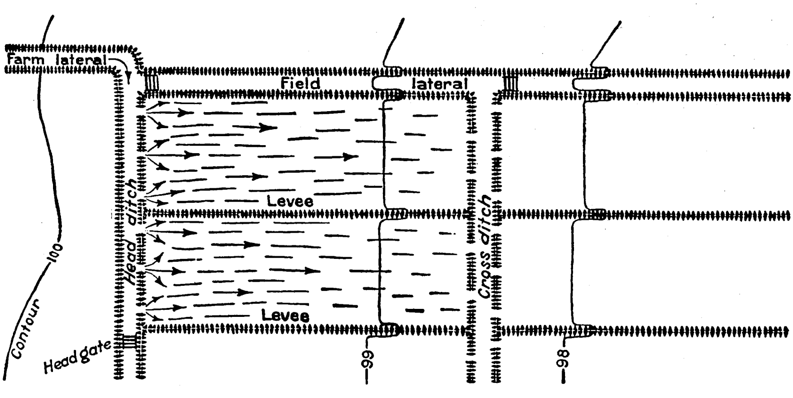

FIGURE 4.—Flooding between border levees.

Where grain is sown a second season as a nurse crop for alfalfa it is usually desirable to corrugate the land between border levees in order to obtain a thorough moistening of the seed bed and give the young alfalfa a good start and a uniform stand. These corrugations usually become filled in after the first season in alfalfa.

WHEN TO IRRIGATE

The character of the soil and subsoil determines, to a considerable extent, the proper time to irrigate. A heavy soil with tight subsoil will receive and hold large quantities of moisture, making it possible to irrigate copiously and at long intervals. If a heavy soil is underlain with gravel the water will drain out and more frequent irrigations will be necessary. The same principle holds true with lighter soils; the lighter the soil and the more open the subsoil, the more frequently will irrigation be necessary, because the water-holding capacity of the light soils is less than that of the heavy soils.

In localities having a small winter precipitation, or where the evaporation is high during the winter months, as is the case along

part of the Pacific coast, in New Mexico, Arizona, southern and eastern Utah, and many other localities, the advantage of irrigating during the nongrowing season has been demonstrated. Where the water supply is deficient, irrigation at any time when the water can be obtained—either in fall, winter, or spring before seeding—is of service in storing moisture in the soil for use in producing the crop. Winter irrigation is not as well understood nor are its benefits as much appreciated as would be the case were the practice more extensive. Irrigation prior to seeding is of great service in localities where the water supply is required by other and more profitable crops later in the season. In the practice of winter irrigation enough water should be applied to saturate the soil to its full depth.

Some difficulty is experienced as a result of irrigating heavy lands in the spring prior to seeding, as the soil dries out very slowly after irrigation and seeding is delayed. In such cases it is best to irrigate the land in the fall if winter precipitation is light. When heavy soils must be seeded in spring, and are too dry to permit germination, then it is desirable to irrigate after rather than before seeding. In this case the corrugation method of application is to be preferred. A second irrigation may then be required before the plants are large enough to shade the ground, in order to prevent damage from the hard crust which forms after irrigation. If the land is not to be irrigated until after the grain is seeded, and has not been plowed in the fall, it should be plowed, double-disked, harrowed, floated, seeded, and corrugated, the operations being performed in the order named. In case the ground is cloddy, the roller or a clod masher may be used either before or after the disk.

Late summer or early fall irrigation is a very effective aid in destroying weeds on foul land. When an early maturing crop like grain is grown the land is irrigated immediately after the crop is harvested to supply moisture with which to germinate weed or other seeds in the soil and to prepare the land for plowing. It is plowed later in the fall and the weeds are turned under. The plowing is followed by disking and by another irrigation, if needed. This method of weed control is to be commended, as it not only rids the land of weeds but also utilizes much green manure.

It is desirable, for several reasons, in growing a crop for grain rather than for hay that the straw be short and not too rank; the ranker the straw the greater the danger of lodging, of rust, and other diseases, and usually the softer and poorer the grain is in quality. The growth of straw may be controlled to a certain extent by holding off the water during the early growth. Excessive irrigation tends to increase the proportion of starch, and this lowers the flour value of the grain. Holding off the early irrigation tends to hasten maturity, which is an advantage where the growing season is short. Grain sometimes starts a second growth if the first irrigation is delayed too long, which reduces the yield. The plant obtains from the soil a great part of its total weight during early growth. While the intermediate growth is taking place the plant undergoes certain changes preparatory to building up the seed. During the later growth the seed is made chiefly from material stored in the plant. More moisture is required during the early and later growth than during the intermediate stage, and it is better to let the grain suffer a little

during the early growth rather than in the late stage, if water cannot be depended upon at both times. Moisture must be present to transport carbohydrate and other material from the leaves and stem to the kernels or they will be shrunken, and the taller the plant the more water will be required. Lack of moisture in the early stages means a short straw, while lack of moisture in the later growth means shrunken grain. It is almost always a good rule to apply some water when the grain is in early milk to effect the transportation of food materials. Irrigation in the final stage of ripening is not good practice.

Many natural and artificial conditions influence the time and amount of irrigation, and the farmer who best understands and makes use of them is most successful. The condition of the soil and the appearance of the plant together afford a practical index of its requirement for water. An experienced farmer does not irrigate loams until a sample taken a few inches below the surface and squeezed in the hand appears barely to hold together.

The appearance of the plant is an excellent indication of the moisture condition where no considerable quantity of alkali is present. The appearance of grain when troubled in the early stages with alkali is somewhat similar to that produced by lack of moisture. Grain which has plenty of moisture is bright green in color; when it begins to suffer for water it turns a dull green, and the lower leaves begin to fire or turn yellow. When these signs are in evidence the crop needs water. It is best to anticipate the appearance of distress a little, as the grain does not show its lack of moisture until some vitality has been lost.

If the first irrigation, or the second in case it was necessary to irrigate to start the seed, is applied when the grain is in early boot, another watering should be given when it is in the late flower, and a last irrigation when it is in the late milk or early dough stage. Four irrigations seldom are required if the first occurs when the grain is in the boot, except in the localities subject to hot winds and excessive evaporation or where the subsoil is porous. Much depends upon the depth and retentiveness of the soil, but if the grain does not require irrigation until it is in late flower it probably will be irrigated again only once—when in medium milk. Better results usually will follow three irrigations than two, even though no more water is needed for the larger number of irrigations. The time of application has as much influence as the number of irrigations upon the yield and quality of grain, and frequently more.

The late irrigation of rank grain makes it likely to lodge. The water softens the stalk at or near the surface of the ground, the plant is top-heavy, and a moderate or hard wind will topple it over. This is a serious danger in windy localities, and the last irrigation should not occur too late in the grain's growth. Dampness throughout the period or too frequent irrigation tends to promote rust.

In growing grain for hay, more irrigations will be required during the early growth, as the object is to secure a rank growth of straw and the crop is cut when the grain is in the milk. The number of irrigations varies from one in the colder climates to five or six in the hot, dry climate of Arizona.

QUANTITY OF WATER REQUIRED

The quantity of water to be applied at each irrigation depends upon the number of irrigations, the depth of soil, the nature of subsoil, the purpose for which the grain is grown, the condition of the crop, climatic conditions, and, from a practical standpoint, the length between water turns, also the available supply, the method of application, the requirements of other crops, the expertness of the irrigator, and the length of time the field has been under irrigation and cultivation.

The quantity of water applied to the crop for the first irrigation varies greatly. As a general rule, the soil is driest at that time and more water will be required than for subsequent irrigations. It is always safe to assume that the ranker the growth of straw the greater will be the quantity of water required at the time the head is making. Water is plentiful in early spring, but at the time the grain is filling the supply usually begins to fail. The general practice is to irrigate heavily in the spring and use less water as the season advances. Often, however, best yields are obtained by the use of the smallest quantity of water at the first irrigation in case only a limited supply is available for the second and third irrigations, in order to hold down straw growth.

On light, well-drained soils underlain with gravel the mistake frequently is made of applying 12 inches or more at each irrigation, while on the heavier and more impervious subsoil it may not be possible to apply more than 4 to 6 inches. From the standpoint of economy of water these quantities might better be reversed, as the heavier soil will retain a large part of the water applied, while the sandier soil will lose much by deep percolation. An average first application is 8 to 10 inches; the second application averages 2 inches less. The third irrigation, which may occur when the water is scarce and in demand for other crops, is likely to be lighter than either the first or the second. The best results will be obtained usually with three irrigations, the first 7 to 8 inches and each of the others 6 inches. These quantities represent the water applied to the crop in the field and do not cover canal losses.

The total annual volume of water applied to the grain crop on the older lands will vary from 1 to 4 acre-feet per acre, the larger quantities being used on the more porous lands and in the warmer climates. An average volume of 1.5 acre-feet per acre will about represent the quantity applied to the crop in the cooler climates and 3 feet in the warmer climates. However, in some sections, as the Imperial Valley, Calif., only about 1.5 feet is applied to barley. This does not include the water lost before it reaches the farm. The losses in canals and laterals will average from 1 to 3 percent per mile, while in gravel and loose material the losses are frequently 10 to 20 percent per mile. These losses, together with those from the distributing ditches and losses resulting from careless irrigation, will average at least 50 percent.

The quantity of water required by new land usually is more than that needed by older land. Very few data are available from which to judge the water requirements of new land, but it is usual to assume that during the first 2 or 3 years 50 to 75 percent more

is required than for old land and 20 to 25 percent more for the following 2 years.

The areas watered by Bear River Canal in Utah afford an excellent illustration of the relative water requirements of new and old lands. During the first few years of irrigation in Bear River Valley a second foot of water was used on 60 to 80 acres, and apparently the land required that quantity. Twenty years later the area actually served by a second-foot of water averaged for all crops 116 acres and for grain crops 163 acres. This represents all the water the farmer actually wanted to apply, as the canal company was under contract to supply a second-foot for each 80 acres. This decrease in the use of water is attributable to the fact that new land has a dry subsoil as a rule and the unevenness of the surface causes much loss from run-off. It is further a result of more careful farming, a better understanding of the water requirements of the crops, a better tilth of the soil, and, very largely, the gradual rise of the ground-water level. Where the ground-water level was 15 to 30 feet below the surface in 1890 it rose to within 3 to 8 feet of the surface in 1905. Drains have since been installed to relieve this land of the surplus water.

What is true of the Bear River Valley is more or less true of all the older irrigated valleys. The experience has been that the ground water gradually rises with continued irrigation. The water level will be highest in the latter part of the irrigation season, gradually subsiding after irrigation has ceased. In many localities the lower lands have been completely waterlogged and made worthless until drained as a result of excessive application of water and the seepage from canals and ditches.

The quantity of water required at the source of supply under average conditions varies with several factors, as heretofore indicated. If it be assumed that the grain requires 1.5 to 3 acre-feet and this quantity represents but half of the water turned into the canal, the quantity of water required at the source of supply will average 3 to 6 acre-feet per acre. This corresponds very closely with the quantity found in practice. For new lands during the first few years it will be found that 50 percent more than the above estimate may be necessary, while frequently in older sections 2 to 4 feet is ample.

RELATION OF IRRIGATION TO RATE OF SEEDING

In raising grain, both with and without irrigation, it has been found that the best rate of seeding depends upon the available supply of water, upon soil conditions, and other factors. If there is plenty of water, the land should be seeded heavily, but if the water is scarce the seeding should be lighter. Experiments in Utah have demonstrated that 1 bushel of wheat to the acre is sufficient when only a moderate supply of water is used, and that when water is scarce three-fourths of a bushel per acre will give larger returns than will heavier seeding.

DANGER OF FAILURE

Partial failure under irrigation may result from the following causes: The application of so much water as to drown the grain or

delay its ripening; the application of too little water, resulting in a shrunken kernel; the application of large quantities of water at the wrong time or too light an irrigation during the filling stage. Grain on heavy soils may be burned or the ground may bake so hard that the grain is injured. In an area containing much alkali the salts may be brought to the surface in large quantities, fouling the land and destroying the grain. Unfavorable weather conditions, such as wind, rain, hail, and frost, may cause serious injury.

VALUE OF IRRIGATED GRAIN LAND

In the larger part of the irrigated section the water has a greater value than the land, there being plenty of land and a very limited water supply. The values of water and of land are very hard to determine separately. Improved land, and especially land devoted and planted to the more valuable crops, such as orchards and truck crops, often is regarded as having high value; yet were this land deprived of its water right it might be valueless. In a new locality land values usually are much lower than in older sections. Very little grain is grown on the land of high value or with high-priced water rights except in rotation with other crops.

Grain is essentially a crop for the farmer with a very limited capital or for the farmer on new land. It is not advisable, however, to grow many crops of grain in succession on new land, as the yields fall off rapidly. After the first year or two grain should be used only in rotation with other crops. It is not a dependable revenue crop for small farms or where intensive farming may be practiced.

EROSION

Erosion is one of the usual penalties of irrigating new land, for the reason that land put under irrigation for the first time is seldom properly prepared. While "wild flooding" is the method of irrigation most often used on new land, it is not conducive to good crops. The water applied in irrigation tends to collect and move toward depressions in such volume that serious erosion results. This erosion may greatly increase the labor and cost of leveling the field as subsequent improvements are made. On the steepest slopes the most effective control of the water is obtained by the corrugation methods and corrugations have been used on slopes of 15 to 20 feet per 100 feet. In porous soils corrugations are apt to lose excessive quantities of water by deep percolation. Flooding from field laterals is recommended as the best method on porous soils where the slope is moderate to steep.

Erosion in the field laterals and head ditches may develop and require the installation of drop structures to prevent serious washing. The need for these structures will be demonstrated by experience, and they are usually combined with outlets or diversion gates. They may be built of wood or of concrete as the farm is further improved and other crops besides grain are grown.

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